



## King's Research Portal

DOI:

[10.1126/science.aaf3420](https://doi.org/10.1126/science.aaf3420)

*Document Version*

Peer reviewed version

[Link to publication record in King's Research Portal](#)

*Citation for published version (APA):*

Kelly, F. J., & Zhu, J. T. (2016). Transport solutions for cleaner air. *Science*, 352(6288), 934-936. DOI: 10.1126/science.aaf3420

### **Citing this paper**

Please note that where the full-text provided on King's Research Portal is the Author Accepted Manuscript or Post-Print version this may differ from the final Published version. If citing, it is advised that you check and use the publisher's definitive version for pagination, volume/issue, and date of publication details. And where the final published version is provided on the Research Portal, if citing you are again advised to check the publisher's website for any subsequent corrections.

### **General rights**

Copyright and moral rights for the publications made accessible in the Research Portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognize and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the Research Portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the Research Portal

### **Take down policy**

If you believe that this document breaches copyright please contact [librarypure@kcl.ac.uk](mailto:librarypure@kcl.ac.uk) providing details, and we will remove access to the work immediately and investigate your claim.

## **Air pollution and transport in urban environments**

Road transport, in facilitating the movement of people/goods and providing employment, supports economic growth and as such, plays a considerable role in global urbanisation. Our consequent dependence on fossil fuels (increasingly diesel in Europe) has however created specific air pollution challenges. Despite many technological improvements over the last 4 decades, our dependency continues to be a major contributor to poor air quality in urban environments. In particular, road transport remains an important source of particulate matter (PM) and nitrogen dioxide (NO<sub>2</sub>). Given the close proximity of traffic emissions to urban residents, attention has increasingly focused on the harmful effects of these pollutants, such as asthma onset and aggravation and impaired lung development in children (1). Here we briefly consider policy interventions already introduced, or under consideration, in two of the world's largest and most economically powerful cities – London, England and Beijing, China and discuss if these policies are good exemplars for other cities to follow. To end we consider some of the modal changes that are required in the future if urban areas are not to grind to a total standstill due to continued pollution growth and transport demand.

### **A tale of two cities - London**

In view of widespread public concern about the health effects of air pollution, the Mayor of London launched an Air Quality Strategy (AQS) in 2002, entitled Cleaning London's Air (2). The primary focus of the AQS was the reduction of pollution from road traffic, reflecting the dominant source of the pollutants of concern (PM and NO<sub>2</sub>) within the city. The AQS sought to reduce London's road traffic emissions in two ways. First, through a decrease in the number of vehicles on the road, and second through reduced emissions from individual vehicles (i.e. modernisation of the fleet vehicle stock). To help achieve the first aim, a Congestion Charging Scheme (CCS) was introduced in central London in February 2003 (3). One of the measures to tackle the second aim was a London-wide Low Emission Zone (LEZ), which was subsequently introduced in February 2008 (4). Although the CCS was initially a success in that it substantially reduced the number of private vehicles entering the central sector of the city, the scheme's effectiveness has subsequently been eroded and congestion is broadly back at pre-2002 levels. The LEZ restricts the entry of the oldest and most polluting vehicles (diesel-engine heavy goods vehicles, buses and coaches, larger vans and minibuses) across greater London. Although black carbon pollution has gradually decreased on many roads in London since 2008, NO<sub>2</sub> has either not changed or increased (5). As a consequence, London does not comply with EU limit values for NO<sub>2</sub> and is unlikely to do so for some time. The main reason for this being the increased share of new diesel car sales – up from 1/10 in 2000 to 6/10 in 2014 and the issue that real-world NO<sub>2</sub> emissions from these vehicles do not comply with current EURO standards (6).

### **A tale of two cities - Beijing**

In contrast to the UK's long industrial heritage, China has undergone rapid industrialisation over the past few decades adding thousands of kilometres of urban road and millions of vehicles. PM<sub>2.5</sub> emissions from traffic have contributed to increasingly poor air quality in Beijing (7) and for some time now it has been sufficient to threaten public health (8). The severity of air pollution in Beijing was first acknowledged at the time when China was bidding for the Olympics games in 1990s. To address the problem the Beijing municipal government introduced the first of 16 stages of air pollution control measures in 1998. Initial measures introduced during this 12 year programme were mainly focused on shutting down small industrial and domestic coal burning stoves and

controlling dust from road and construction sites, as well as phasing out old vehicles that did not meet emission standards. These standards however, were much less strict compared with those in place today.

With the fast urbanization and social and economic development in Beijing, the measures in the later stages became more comprehensive as they needed to deal with the complicated nature of the air pollution sources in Beijing. These included long term and strategic measures, such as improving the energy profile by replacing coal with natural gas, building the infrastructure of a public transit system with 554 km of subway, and introducing strict vehicular emission standards equivalent to EURO V. Besides these, aggressive measures were taken during the Beijing Olympics (2008) (9) and the APEC meeting in Beijing (2014), to reduce the number of vehicles on the road by allowing cars to drive based on the last digit of the car licence number. This measure resulted in substantial temporary reductions in congestion and pollution concentrations within Beijing and considered so successful, that after Beijing Olympics it became a routine rule and now every weekday Beijing has roughly 20% fewer cars on the roads as a consequence.

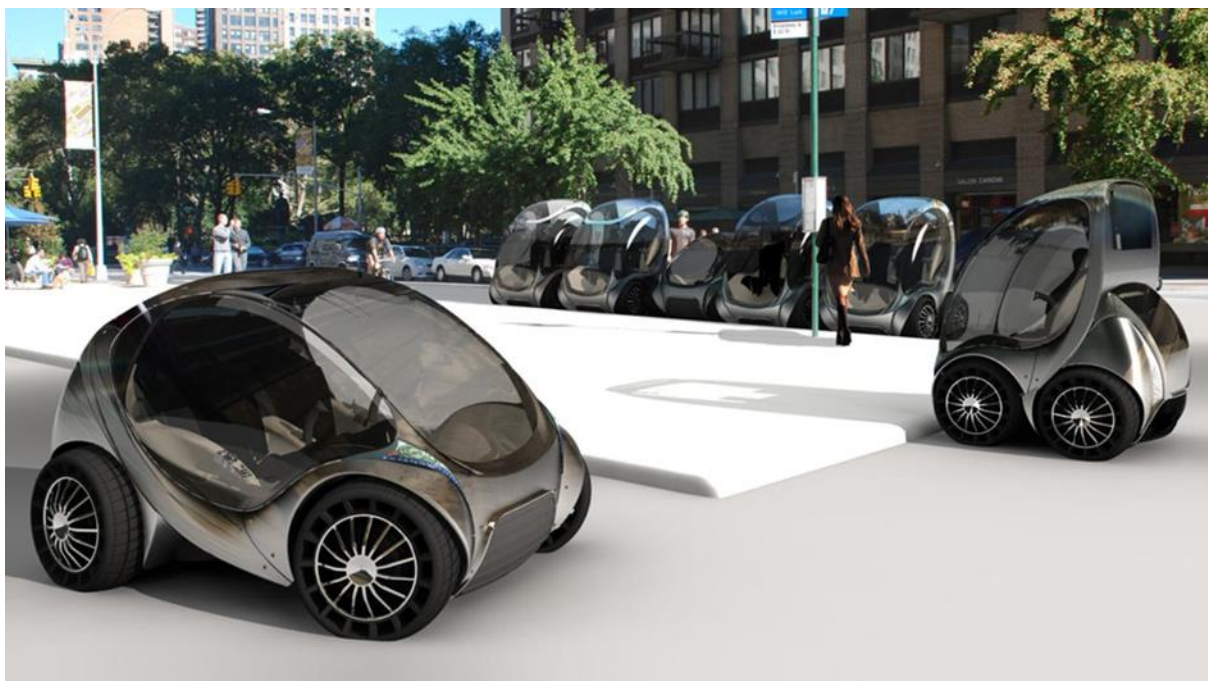
With all the efforts to control air pollution, Beijing PM<sub>2.5</sub> concentrations have started to fall in recent years. However, these benefits have been compromised to some extent by the rapid growth in vehicle numbers, from 1.5 million in 2000 to 5.6 million in 2015. To start dealing with this problem the Chinese Government introduced a range of vehicular emission policies: including a lottery system for new car licence plates and further modernisation of the fleet. Given that the vehicle fleet in China, especially in Beijing, now has the most advanced engine technologies (10) further control measures to cut vehicular emissions will necessitate further restrictions on car movements. Importantly, the Chinese government have not incentivised the uptake of diesel vehicles into the private fleet (11). As a consequence, in line with other countries such as Japan, the problems of diesel NO<sub>2</sub> emissions contributing to Beijing's poor air quality have been avoided.

### **Looking to the future**

Experiences gained in trying to address air quality problems in London and Beijing clearly indicate that more fundamental changes in urban transportation systems are required if air quality improvements are to be achieved and city streets are to be once again more pleasant environments. In London, an ultra-low emission zone (uLEZ) is planned for introduction in 2020 (12). However, banning all but the cleanest vehicles and incentivising the benefit of zero emission cars and taxi's in a small area of central London will still be insufficient to achieve compliance with NO<sub>2</sub> standards until at least 2025 (13). In Beijing if car ownership levels are allowed to move toward US levels (840 cars per 1,000 people), the city will grind to a standstill through excessive congestion and air quality will suffer further. Car ownership must therefore continue to be strictly controlled. In many European cities however, attitudes appear to be changing regarding car ownership. The urban youth of today it seems would rather use services like Uber to travel rather than owning their own car. Furthermore, recent polls in London associated with the forthcoming Mayoral elections put air quality issues high on the political agenda and indicate that further tightening of vehicle use in the city may occur. Cars promote a sedentary lifestyle and the increasing modal shift to cycling and walking has associated health benefits for urban dwellers. In London we now live in the age of bike-share and active travel schemes hence helping to push back against the obesity epidemic sweeping the world (14).

Recognising that congestion experienced by drivers entering cities is bad from both an economic and an air quality point of view several states in the Northeast of the USA introduced electronic toll collection (ETC) technology which helped reduce delays at toll plazas. Furthermore, improved traffic flows near these toll plazas were subsequently linked to improved health of infants born to mothers living nearby (15). Other interventions, such as the Hoy No Circula (HSC) program in Mexico City have proved less successful. Introduced in 1989 to address the terrible air pollution problems in Mexico City the HSC banned most drivers from using their vehicle one weekday per week on the basis of the last licence plate digit (16). Although the program was largely successful in removing vehicles from the roads no evidence could be found that this led to increased usage of public transportation or indeed improved air quality (16).

The car industry has recognised the need for change and companies like BMW and Ford have launched car-share schemes. Car sharing has obvious benefits to the city. Zipcar estimates every shared vehicle replaces up to 20 private cars, thus reducing total vehicle miles and land devoted to parking. The car industry is also pushing forward the development of city friendly plug-in electric vehicles. Worries over battery-life and the lack of coordinated charging networks however have held back vehicle sales even when generous government subsidies were available. Encouragingly, in the UK the uptake of electric vehicles has jumped in the last two years from a fleet of 3500 to over 50,000 vehicles suggesting that the tide is turning in the favour of zero emission vehicles. In contrast, goals for fuel cell (hydrogen) powered cars has not been achieved, again due to the limitations of the fuelling network and high initial vehicle cost.



As cities continue to grow in size and population, even zero emission vehicles are not the solution. The need to move increasingly large numbers of people efficiently around a city can only be achieved by expanded mass transit systems. The increased use of bus networks and traditional subways are providing city dwellers with more flexible, cheaper, and less polluting options. For instance, China is

building 87 new mass transit rail lines over the next five years. If construction continues on this pace, then China's cities will have half of the world's metro tracks by 2050 (17).

Rapid transit systems offer only a partial solution to city congestion and poor air quality as many users may not live within easy walking distance to the transit points. To be effective rapid transit systems need to be linked with other transport options at the start and end of the journey. The creation of an Autonomous Mobility-on-Demand (A-MoD) network may solve this problem (17). Modelled after bicycle-share programmes, users will have access to a network of Lightweight Electronic Vehicles (LEVs) distributed at charging stations throughout the city. Summoning one of these vehicles through a smart phone app provides the ultimate convenience and allows the user to abandon the LEV when they reach their destination as it will then find its own way back to a charging station or a new customer.

In the city of the future, mass public transport systems may result in many more car-free roads which will transform the landscape and enhance the urban experience (Figure). Moving towards a healthier environment is dependent upon a host of factors: continued and exacting scientific research, the translation of the latter into realistic and effective policies as well as achieving the right public attitude and behaviour (18). The reward will be infinite as such a cohesive and comprehensive approach will contribute in a significant and cost-effective way, to an improved health and quality of life for our current global population as well as future generations around the world.

## References

1. RCP/RCPCN report. Every breathe we take; the lifelong consequences of air pollution. (2016) <https://www.rcplondon.ac.uk/projects/outputs/every-breath-we-take-lifelong-impact-air-pollution>
2. GLA. The Mayor's Air Quality Strategy, Cleaning London's Air. The mayor of London, Greater London Authority, London (2002)
3. Kelly, FJ, Anderson HR, Armstrong B et al. 2011. Impact of the Congestion Charging Scheme on Air Quality in London. Part 1. Res. Rep. Health Eff. Inst. 155: 1-72.
4. London Mayor. (2007) <http://www.tfl.gov.uk/assets/downloads/LEZMayors-Statement.pdf>.
5. Fuller GW and Font A. Evaluating the effectiveness of policies to abate air pollution from traffic in London 2010 to 2015. ERG, Kings College London (2015). <http://content.tfl.gov.uk/roadside-air-quality-trends-in-london-identifying-outliers-part-1.pdf>
6. Carslaw, D.C. and Rhys-Tyler, G. (2013). New insights from comprehensive on-road measurements of NO<sub>x</sub>, NO<sub>2</sub> and NH<sub>3</sub> from vehicle emission remote sensing in London, UK. Atmospheric Environment, Vol. 81 339-347.
7. Chena Y, Schleicher N, Fricker M, Cen K, Liu XL, Kaminski U, Yu Y, Wu XF, Norra S. Long-term variation of black carbon and PM<sub>2.5</sub> in Beijing, China with respect to meteorological conditions and governmental measures. Environmental Pollution, 212, 269–278, (2016).
8. Yang G, Wang Y, Zeng Y, Gao GF, Liang X, Zhou M, Wan X, Yu S, Jiang Y, Naghavi M. Rapid health transition in China, 1990-2010: findings from the Global Burden of Disease Study 2010. The Lancet. 381(9882): 1987-2015 (2013).
9. Wang, M., Zhu, T., Zheng, J., Zhang, R.Y., Zhang, S.Q., Xie, X.X., Han, Y.Q., Li, Y., 2009, Use of a mobile laboratory to evaluate changes in on-road air pollutants during the Beijing 2008 Summer Olympics, Atmos. Chem. Phys., 9(21), 8247-8263

10. Hodges P. China's new car market goes ex-growth as used car sales take off.  
<http://blogs.ft.com/beyond-brics/2015/06/30/chinas-new-car-market-goes-ex-growth-as-used-car-sales-take-off/>
11. Cames M and Helmers E. Critical evaluation of the European diesel car boom - global comparison, environmental effects and various national strategies. *Environmental Sciences Europe*. 25:15 (2013).
12. GLA 2014. Ultra Low Emission Zone Update to the London Assembly  
<http://www.london.gov.uk/sites/default/files/ULEZ%20scrutiny%20briefing%20%E2%80%93%20February%202014.pdf> Accessed March 2016
13. Howard R, Beevers S, Dajnak D. Up in the Air: How to solve London's air quality crisis: Part 2. King's College London and Policy Exchange 2016.  
<http://www.policyexchange.org.uk/publications/category/item/up-in-the-air-how-to-solve-london-s-air-quality-crisis-part-2> Accessed April 2016
14. NCD Risk Factor Collaboration. Trends in adult body-mass index in 200 countries from 1975 to 2014: a pooled analysis of 1698 population-based measurement studies with 19.2 million participants. *The Lancet* 387, No. 10026, p1377–1396, 2016
15. Currie J and Walker R. Traffic congestion and infant health: Evidence from e-Zpass. *American Economic Journal: Applied Economics* 3: 65-90, 2011
16. Davis LW. The effect of driving restrictions on air quality in Mexico City. *Journal of Political Economy* 116: 38-81, 2008
17. Ryan Chin. Solving transport headaches in the cities of 2050.  
<http://www.bbc.com/future/story/20130617-moving-around-in-the-megacity>  
Accessed April 2016
18. Kelly FJ and Fussell JC. Air pollution and public health: emerging hazards and improved understanding of risk. *Environmental Geochemistry and Health*, 37, 631-649, 2015.

Frank J. Kelly (frank.kelly@kcl.ac.uk)  
NIHR Health Protection Research Unit in Health Impact of Environmental Hazards  
MRC-PHE Centre for Environment & Health  
King's College London  
London SE1 9NH, England

Tong Zhu (tzhu@pku.edu.cn)  
State Key Laboratory for Environmental Simulation and Pollution Control  
College of Environmental Sciences and Engineering  
Peking University, Beijing 100871, China